The Open Court

A MONTHLY MAGAZINE

Devoted to the Science of Religion, the Religion of Science, and the Extension of the Religious Parliament Idea

Founded by Edward C. Hegeler

VOL. XXXVII (No. 1) JANUARY, 1923 No. 800

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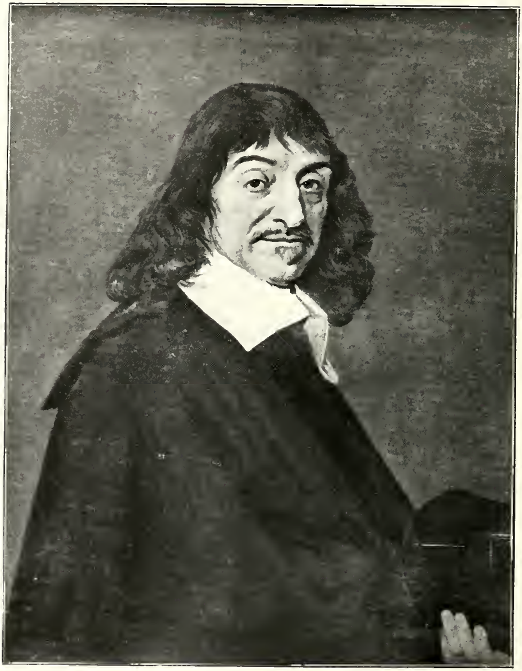

DESCARTES

Frontispiece to The Open Court.

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THE SECRET OF LIFE.

BY ALBERT GEHRING

THE question concerning the nature of life is a simple, mechanical one. The real difficulty arises when we consider the difference between conscious and unconscious life. What is it that endows the protoplasm, at a certain point, with the faculty of feeling,—that, indeed, is a question which is baffling in its elusiveness.

But life as such, as it is shared by plants as well as animals, and lies outside the realm of consciousness, is a comparatively simple affair. The question here becomes: what is it that underlies the chemical and physical differences, not so formidable as to defy analysis, that separates the organic from the inorganic realm?

Before we attack this question, we must of course determine what the chemical and physical differences under consideration really are. Verworn has gone into this matter in some detail.[1] He subjects to criticism fourteen supposed criteria of life, with the result that all, barring a single exception, are found inadequate. The only thoroughgoing and unfailing distinction which this author recognizes between living and dead matter is found in the fact that the former contains albuminous substances, with their highly complicated chemical formulae, while the latter does not. He rejects metabolism as a distinction, because he maintains that this process can also be duplicated in the inorganic realm, and he cites the method by which nitric acid when brought into contact with sulphur dioxide, is transformed into sulphuric acid and nitrogen dioxide. If water and air are constantly added, he says, the nitrogen dioxide will ever again pass into nitric acid, which once more gives

[1] *Allgemeine Physiologie*, Jena, 1897, p. 121 *et seq.*

up a part of its oxygen to new quantities of sulphuric acid, "so that the molecule of nitric acid is constantly broken down through a loss of oxygen, and renews itself again through a taking-up of oxygen." However, it is admitted by our author that such cases are rare, and hardly occur in nature, where the conditions are not artificially produced by man. But in making this admission, he really destroys his objections to metabolism as a criterion. For we are dealing, in the case of living matter, with organisms, which are capable of existing and sustaining their peculiar vital processes —whatever these may be—by themselves. The fact that metabolism can be duplicated artificially by man, is no argument against the distinction in question, for the mechanisms through which this end is attained are fashioned and regulated from without, and the process would immediately collapse if it were not kept going by human help. If we wish, we may substitute the term "spontaneous metabolism" for the other, and we shall then have a distinction which is unmistakably characteristic of life. These two distinctions,—spontaneous metabolism and the presence of albuminous matter,—are those which can safely be drawn from the reasonings of Verworn.

According to Ostwald, there are three distinguishing marks of living organisms: they are *stationary* in form, not *stable;* they have the capacity for *selfacquisition of nutrition;* and the capacity for *reproduction.*[2] By a stationary body Ostwald means one which is not,—like a stable one,—"at rest or unchangeable in all its parts," but which, "though it seems unchangeable in its form, internally undergoes a constant change of its parts." A brass faucet is a stable body, the stream of water issuing from it is stationary. But as our author makes the further statement that "*change of substance, metabolism,* appears as a necessary property of the stationary body," we may substitute this term for the other. It is more specific.

According to Calkins, there are five marks which "distinguish living from all other kinds of matter." They are: chemical composition, power of waste and repair, growth by intussusception, power of reproduction, and adaptability.[3] As with Verworn, albuminous compounds are specified as the peculiar characteristic of living matter. The power of waste and repair is merely another

[2] *Natural Philosophy,* N. Y., 1910, p. 163 *et seq.*

[3] *Biology,* N. Y., p. 6 *et seq.*

name for metabolism. Growth by intussusception is a new quality, not mentioned by the other writers, but as metabolism involves intussusception, only the feature of growth is really new. Adaptability is described as the "capacity to vary under changed conditions of the environment."

So we have ten criteria, disposed as follows:

Verworn	Chemical Composition Metabolism
Ostwald	Metabolism Reproduction Self Acquisition of Nutrition
Calkins	Chemical Composition Metabolism Growth Reproduction Adaptability

Metabolism is mentioned three times, chemical composition and reproduction appear twice each, and the other three distinctions once. By combining the three sets of criteria and cancelling the duplications, we obtain the following list:

Metabolism
Chemical Composition
Reproduction
Self Acquisition of Nutrition
Growth
Adaptability

The question now arises: how can we explain these features, what is the underlying cause and basis of these peculiar manifestations which we call vital?

In an enquiry like this, it is desirable to descend to elementals, dealing with the simplest appearances of the things under discussion. So that, having determined what the appearances of life really are, in their ultimate analysis, it behooves us next to ask, what is the smallest particle of matter in which these appearances may be found?

Generally the cell has been regarded as the unit of life. But in the case of inorganic bodies, we find that it is the molecule or atom to which the substances are reducible, and so the question naturally arises: is life not similarly existent already in units that are smaller than the cell,—is there not a molecule of living matter, just as there is a molecule of salt or water? General considerations would urge toward the adoption of this conclusion. At least, analogy would forbid us to conclude otherwise until we are confronted with reasons that compel us to do so. Now, protoplasm has been analyzed chemically, and the elements which enter into its composition have roughly been determined. But when so determined, they no longer belong to a living, but rather a dead body, with no possibility of resuscitation. The analysis which seeks to wring its secret from nature, destroys the very phenomenon which it endeavors to explain. Inorganic bodies are not similarly recalcitrant. They do not defy inspection. We can analyze them into their molecular components without destroying their identity, or at least the possibility of reconstruction. But try to determine the composition of life, and you have something that is life no more. So it would appear as if there might indeed be a difference in this respect between living and lifeless matter. And this impression is strengthened by a review of the features characteristic of vitality. Metabolism, reproduction, self acquisition of nutrition, growth, and adaptability,—all are dynamic, not static, in nature. So that we are tempted to conclude that there must be something dynamic, likewise, about the remaining feature—chemical composition—and that the static molecule, as we know it, cannot be the elemental particle of vitality that we are after.

Observation cannot help us here, for we have no microscopes fine enough to register the activities of the atoms which constitute the "molecule" of life. We are thus reduced to supposition. And of this let us now avail ourselves.

Let us imagine a molecule which is not fixed and stable, but undergoes a series of internal changes,—one state ever leading to another, but the whole retaining its general appearance of constancy. To symbolize this, let us imagine two elements—X and Y—which are capable of entering into union with each other in the proportions of 2:1, 3:1, and 3:2. At first we have X_2Y. An atom of X is now added and the molecule becomes X_3Y. The addition of an atom of Y yields the form X_3Y_2. And another atom of X leads to X_4Y_2, which splits into two of the original molecules. Thus we have gone through a little cycle of changes, which has brought us back to the point of departure.

It is not to be supposed, of course, that anything just like this actually takes place in nature. The example was merely given to symbolize, however crudely and faultily, a procedure which would answer our purpose. What we wish to bring home is the idea of a molecule which is not static, but passes through an internal cycle of changes which, as we shall later see, will explain the phenomena of life. Very likely the "molecule" would be tremendously complicated. It might consist of various submolecules. Let us, by way of hypothesis again, start with the supposition that there are three of these,—*a, b,* and *c.* Certain changes might now be supposed to take place in *a.* Some atoms are added, which leads to the expulsion of others. These are taken up by *b,* which likewise expels some of its members and hands them over to *c.* *C* takes up these in turn, and similarly casts off a few superfluous members. The process is like that in card games, where each player receives certain cards from his neighbor on the left, and in turn passes on a similar number to the neighbor on the right And if we might now suppose this process to be continued in supplementary order, every submolecule taking up what it formerly expelled and expelling what it formerly took up, we should arrive at the starting point again, and should have the material of an endless series of inner changes, closely resembling the metabolistic changes of life.

This idea, too, is purely fanciful. It is not to be supposed that anything just like this, either, takes place in the vital molecules. But once more, our purpose is only to bring home the conception of a molecule with "inner circulation" of elements, however artificially and mechanically we may do this. Many modifications of the process would be conceivable. Thus, instead of adhering to the same number of submolecules, as in the previous example, we might imagine a variation in their number. Some of the submolecules, for example, might, through the constant addition of atoms, fall apart into smaller unities. These, too, would grow in size, until finally they melted together again into the original number, but with an increase in size. Thus, we might have three submolecules to begin with,—*a, b,* and *c.* These split into four, five, or even more,—of smaller volume and different composition. But with the increase in atoms they fall back once more into the original submolecules,—but now we have *2a, 2b,* and *2c.* That is, the molecule has grown to twice its original size.

In some such ways me might typify the inner changes in our albuminous "molecules." What the exact nature of these changes is, we do not know. But that there are cyclical changes of some sort, and that this is the distinguishing feature of life, is the proposition which we would seriously defend.

It is the wonderful "elasticity" and combining power of carbon,—that peculiar element of life,—on which all this may be supposed to rest. The compounds of carbon are said to outnumber by far those of all the other elements put together. Moreover, there is a complexity to some of these compounds, notably the organic ones, which is to be found nowhere else. And many of the compounds stand in definite relations to one another and can be arranged in series, as is shown in the following typical reproduction of symbols:—

$$
\begin{array}{l}
C\,H_4 \\
C_2H_6 \\
C_3H_8 \\
C_4H_{10} \\
C_5H_{12} \\
C_6H_{14} \\
C_7H_{16} \\
C_8H_{18} \\
C_9H_{20}
\end{array}
$$

It is known that the number of atoms in the substances which peculiarly constitute life reach into the hundreds. Is it not conceivable, then, considering the "slippery," protean nature of carbon, for certain changes to take place within the vital "molecule" itself, and certain combinations to pass into others, somewhat upon the analogy of the series above, where the mere addition of a constant number of atoms produces one substance after another? May there not be a definite succession of forms, similar to the side-by-side arrangements of homologous members; and may not this succession itself, the process, be the basis of the metabolism which constitutes life? According to this conception, there would be no single, definite molecule of living matter, expressible in number and grouping of atoms, but only a successive series of groupings, which would represent the life-process in their totality.

The hypothesis which we have thus developed would serve as an explanation of all those properties of life which have been posited by our three authorities. To begin with, albuminous compounds, furnishing as they do the greatest number and complication of atoms, would be the playground of this scene of ferment. Most other compounds are too simple and stable for this purpose. Albuminous matter alone seems to be composed of the requisite number and kind of atoms. Secondly, the process of inner change which we have sketched is the basis, as just said, for the metabolism which is the most prominent feature of life. In fact, it *is* a metabolism in miniature. The power of self acquisition of nutrition is also involved in the process as described. And growth is a natural, almost inevitable accompaniment of the same. We have merely to imagine that there are more atoms taken up into the process than are eliminated, and we shall have growth. Reproduction, to continue, is but little more than growth, in its simplest embodiments. The organism merely keeps on increasing in size, until at last it splits into two separate organisms. As for the remaining characteristic of life, adaptability, that too is in harmony with the process. It is easier to conceive of adaptation in the case of a changing body than in the case of a fixed and stable piece of matter. The many-sidedness of carbon, especially, and its capacity for endless combination, seem to be the very requisite for adaptability.

So then our hypothesis accounts for every feature of life as posited by Verworn, Ostwald, and Calkins. Indeed, if true, it would be the veritable explanation of life, in its material aspects. And it would likewise throw light on numerous related phenomena. It would show us, for example, why it is impossible to obtain the exact chemical formulae of living substances. Subject these substances to analysis and you stop the circulation which is the very essence of their being. Instead of a living picture of activity, you merely obtain a dead precipitate. And this stoppage of the process corresponds to,—in fact is the phenomenon of death. It would also show us why certain of the lower organisms are destroyed by heat, but not by cold. Cold, we may suppose, temporarily arrests the vital process, but does not destroy it. The position of the atoms relative to each other is not changed. The atoms are merely drawn together; they "hibernate" for the time being, but with the renewed advent of heat resume their circulation, and life appears once more. Intense heat, however, would drive apart and disarrange the atoms completely. Their peculiar vital "setting" being lost, they would relapse, upon cooling, into passive, lifeless particles, similar to any bit of inorganic matter.

Indeed, our hypothesis might even throw light on the different lines of development which living germs may follow, and thus on the phenomena of heredity. The peculiar complexity of the living molecule, we can imagine, would leave room for various modes of inner circulation. It would be like a checker board, on which combinations of great variety would be possible. Now, in some cases one combination would be followed, in some another. But the substances, once having started in particular rhythms, would become "set" in the same, and tend to repeat them ever after. Like pieces of fireworks, they would "go off" in their own particular directions. (A rocket, for example, is set so that it will soar toward the sky, a wheel so that it will circle about its axis,—yet the propelling principle is the same.) So living germs would start off in different directions. But once having started, they might again be "deflected" in particular ways, which would thereupon become habitual, and once more serve as the starting points of later "deflections." Thus, slight differences in the original "settings" might become the basis of many future changes, and would account, in part, for the mysterious phenomena of development and heredity.

The advantage of this method of viewing the situation is, that it introduces the concept of motion. The metabolistic exchange of atoms in the intra-molecular cycle must be viewed as an extremely rapid motion. Now, as long as the seeds and germs which generate living beings are regarded merely as static particles of matter, it seems hopeless to explain the process by which they develop into complex organisms. But view them as settings which, when introduced into the proper environments, will generate their specific motions, and it becomes comprehensible how these motions, ever continuing and gathering new momentum, will indeed develop into something that is unforeseen in the germ or seed. A more unobstructed motion by itself may already yield surprising results, as witness the mass of snow obtained from continuously rolling a snowball over the ground. But further results may ensue when the motion is obstructed or combined with outside influences. Thus two billiard balls rolling over a table, one of which was struck at its top and the other at the bottom, present exactly the same appearance. If both were suddenly to be stopped by the hand or allowed to roll on indefinitely, hardly any difference would appear. But let them come into collision with another ball, and the first will thereupon continue along its original course, while the other will recoil and retrace its path in a backward direction. So. little differences of propulsion in the seed or germ, metaphorically speaking, may lead to different reactions upon contact with the environment, reactions, furthermore, which will be much more varied and complex than those of the billiard balls, in accordance with the greater complexity of the germ and its inner motion.

We see thus how all the important manifestations of life would be explained, or at least have light thrown on them, by our hypothesis. It would remain now for chemical investigation to take up this hypothesis, in case it seemed sufficiently plausible, and show that it actually has basis in fact.